Quantitative Experimental Results:

Automation to Support Time-Critical Replanning Decisions

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Time-Critical Decision-Making

ie. Combat flight route planning

- Aviation, medicine, chemical and energy production, finances

Complex Problem

- Unstructured aspects
- Multiple competing interests and goals
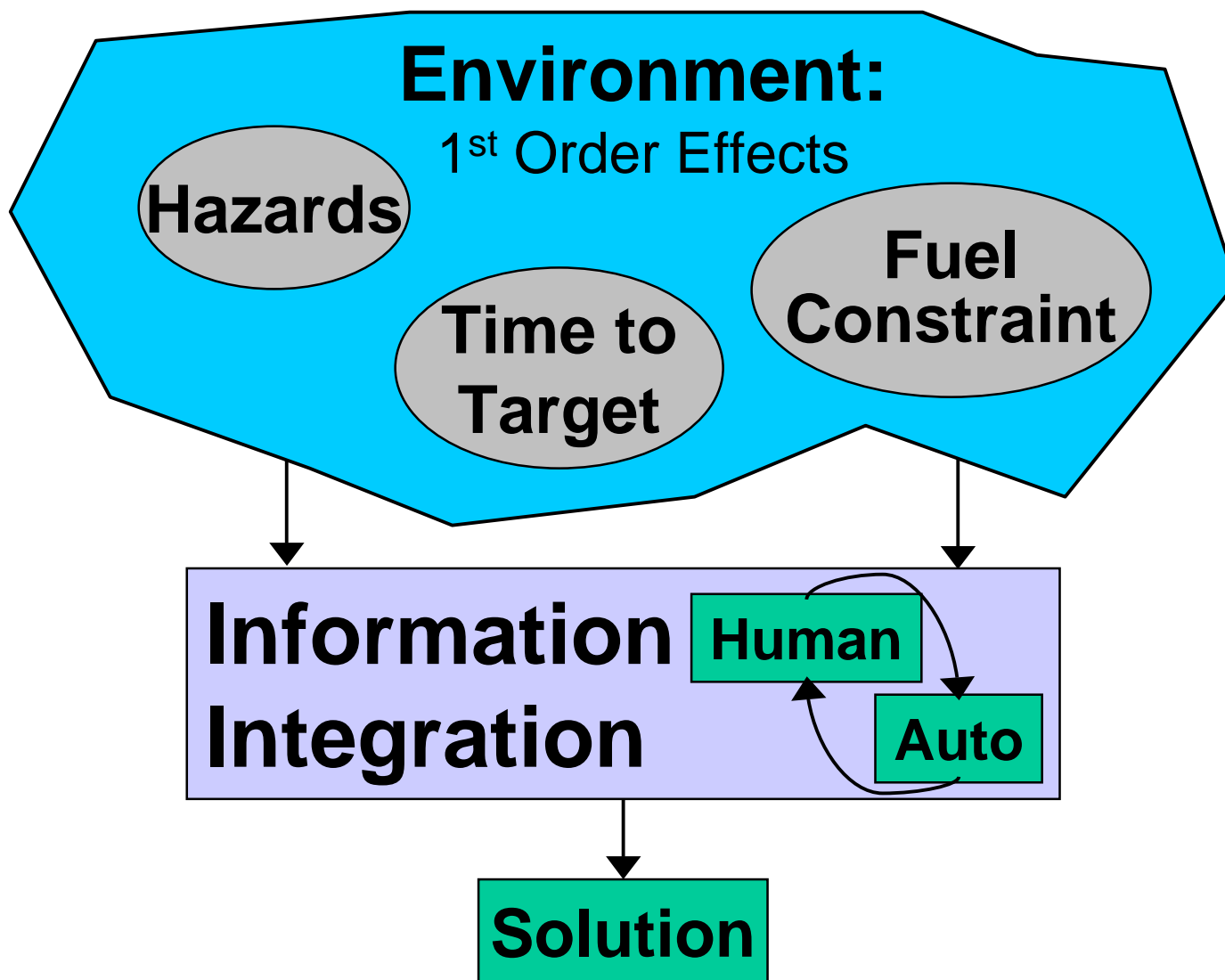- Time pressures

Automation Integration

- Cannot "see" everything (sensor limitations)
- Human may not understand basis for automated decisions

Experimental Goal

Discover the relationship between **time pressures**, **automation assistance**, and the resulting **decision performance**, both quantitatively and subjectively.
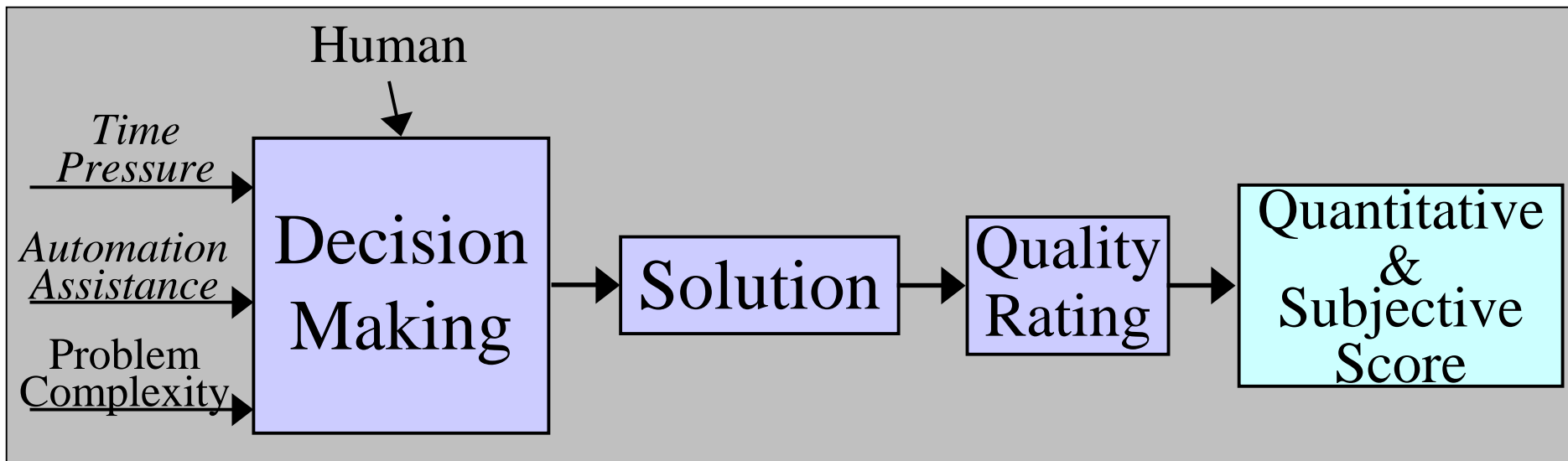
Experimental Protocol
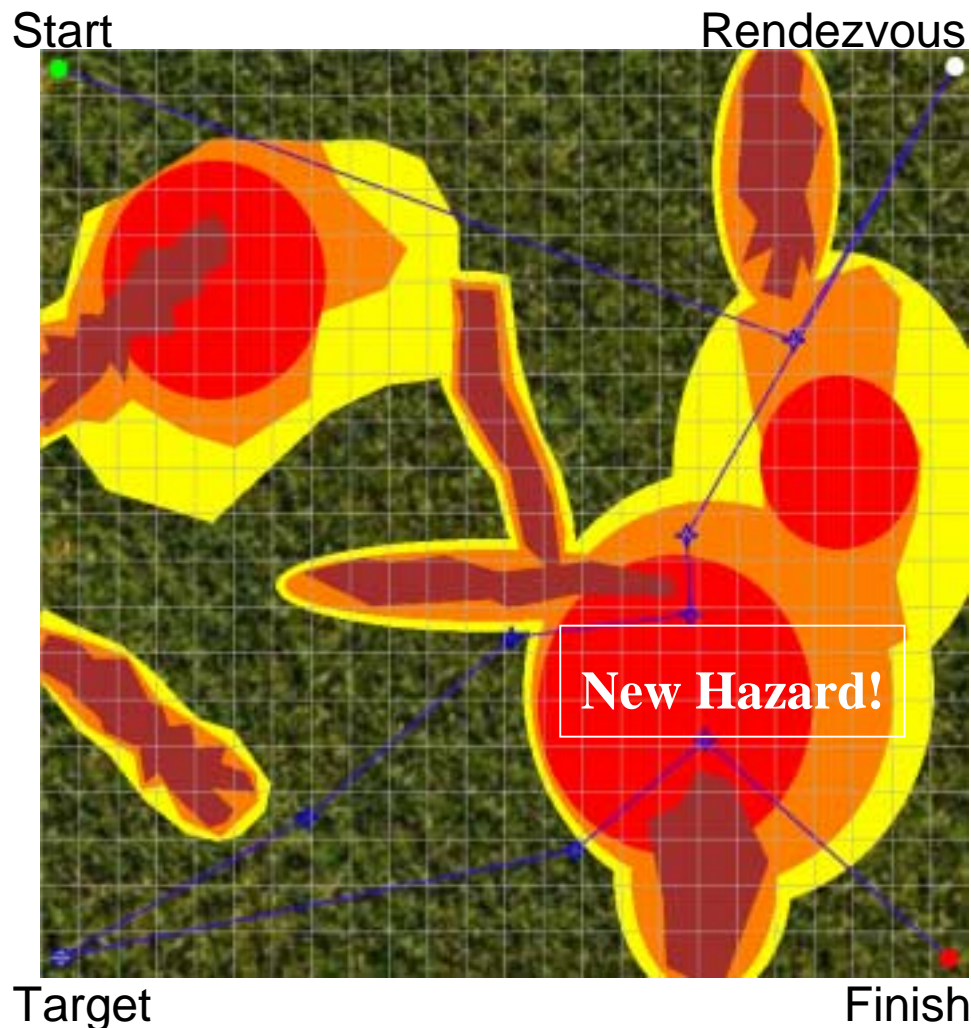
1. View Preplanned Mission

2. Change in Environment

- Hazard, Time to Target, or Fuel Update

3. Route Suggested with Varying Automation Assistance (BLUE)

4. Subject Modifies Flight Route Under Time Pressure

➤ **Minimize Threat Exposure and Time to Target Deviation**

➤ **Meet Time to Target and Fuel Constraints**

Start   Rendezvous

New Hazard!

Target   Finish

Automation Categories

<u>None</u>: No Automation

- original route remains

<u>Time/Fuel</u>: Constraint Information Only

- meets time to target & fuel constraints

<u>Hazard</u>: Hazard Information Only

- avoids/minimizes hazard exposure

<u>Full</u>: Integration of Constraint + Hazard Information

- minimizes hazard exposure + meets constraints

Time Pressure

- 20, 28, 40, 55 seconds (logarithmic)
  - capture performance change

- Unlimited time to find individual's optimal performance

Dependent Variables

1. Quantitative human performance measured by route cost at end of time pressure.

   Cost = Hazard Exposure (linear) + Time to Target Deviation (exponential)

$$Cost_{Route} = \ln\left\langle A\left[\sum_{1}^{\#colors}\left(Length_{RouteSegment} * Cost_{Color}\right)\right] + B\left[a_1 * \left(\exp\left(b_1 * \left|\frac{t}{t_0}\right|\right) - 1\right)\right]\right\rangle$$

   Fuel = constraint

2. Subjective evaluations.

- 14 subjects: students, ave age = 25, 3 pilots, 3 females
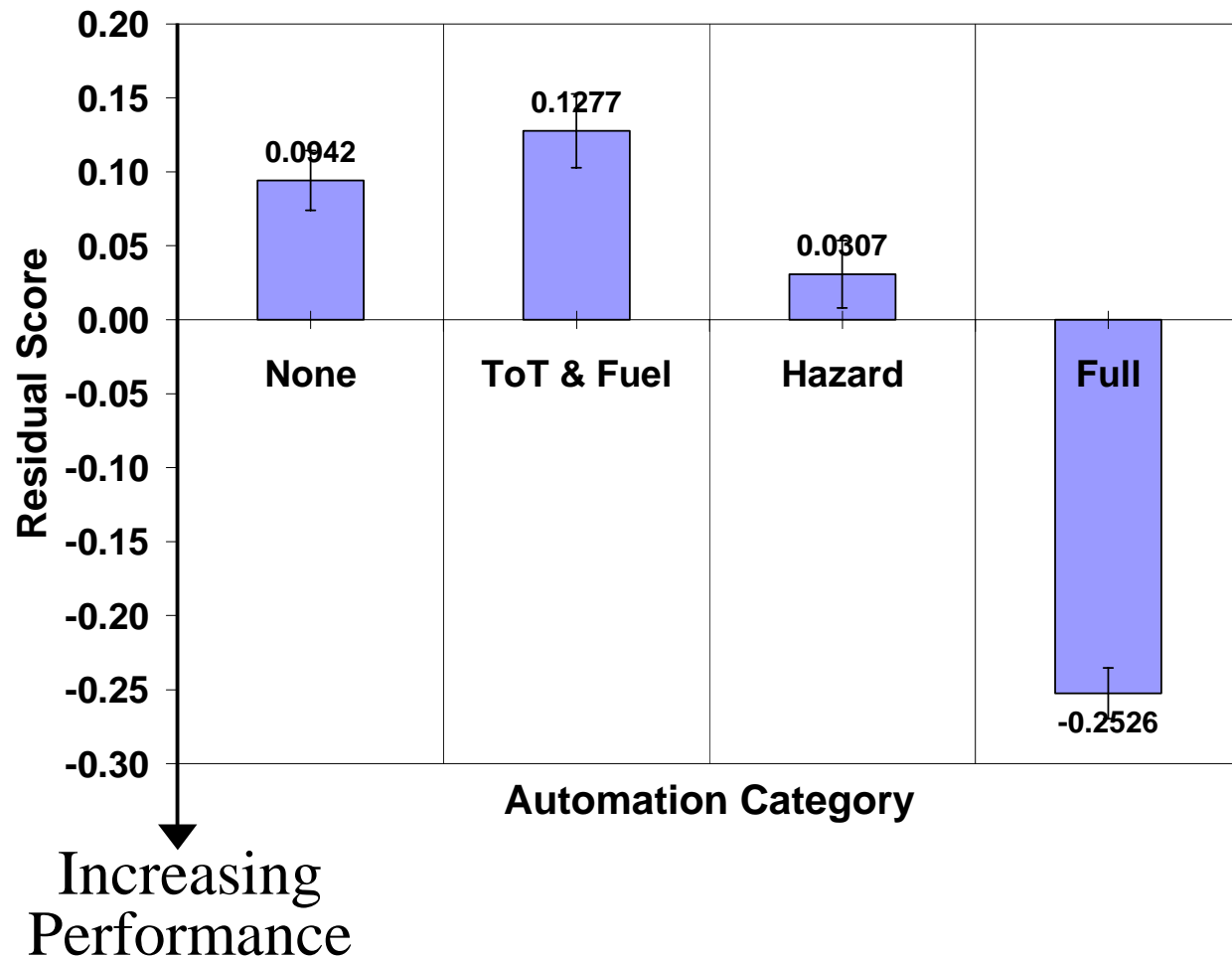- 3 hrs: 2 hr training, 1 hr data collection

Test Matrix:

Time Pressure

		20	28	40	55
Auto Category	None	M1	M2	M3	M4
	ToT/Fuel	M2	M1	M4	M3
	Hazard	M3	M4	M1	M2
	Full	M4	M3	M2	M1

- Greco-Latin Square Design
- 4 base maps (M), each rotated for 16 effective scenarios

Automation Effects

- Repeated Measures ANOVA

- Full auto assistance is sig. best

- Hazard auto assistance is sig. better than none

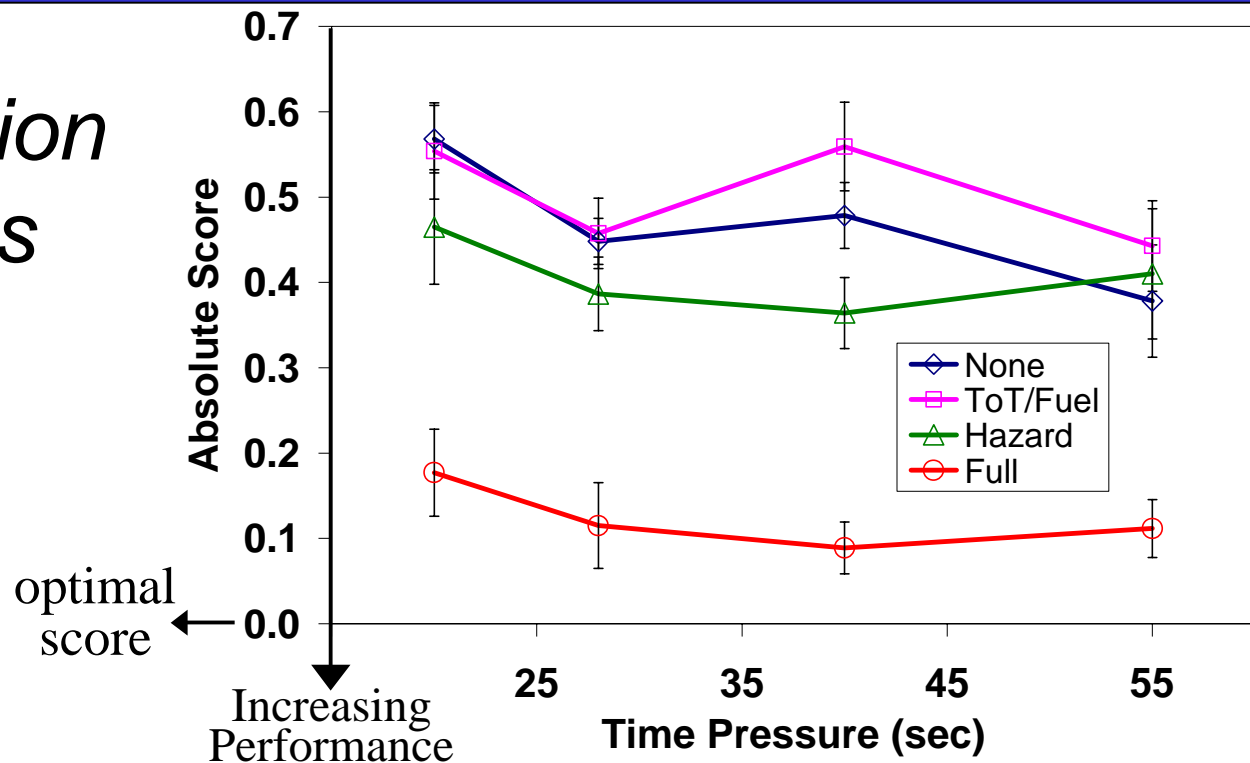Bar chart — Residual Score vs. Automation Category

- None: 0.0942
- ToT & Fuel: 0.1277
- Hazard: 0.0307
- Full: -0.2526

Increasing Performance

Time Pressure Effects

- Repeated Measures ANOVA

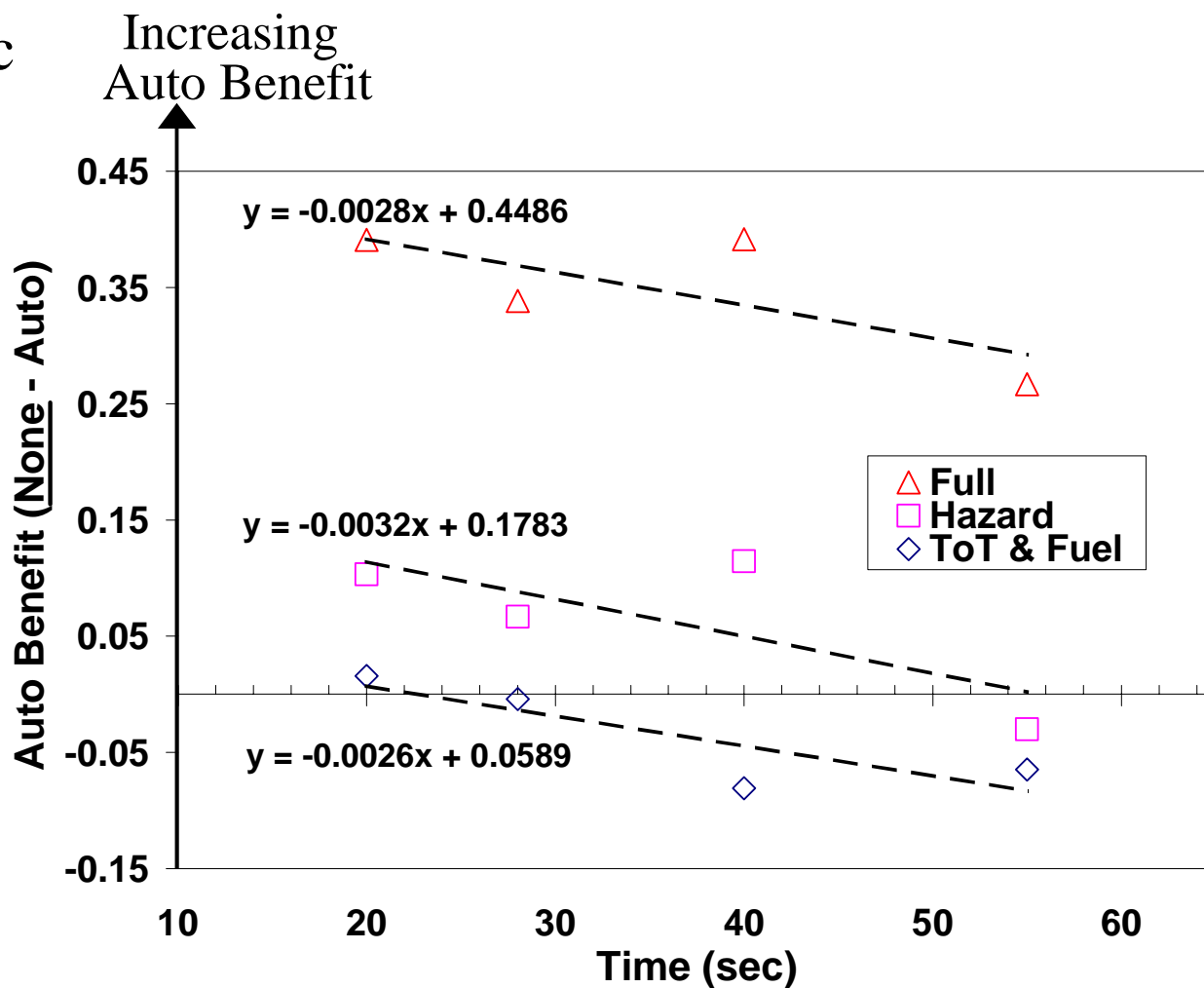- No sig. performance improvement after ≅ 28 sec
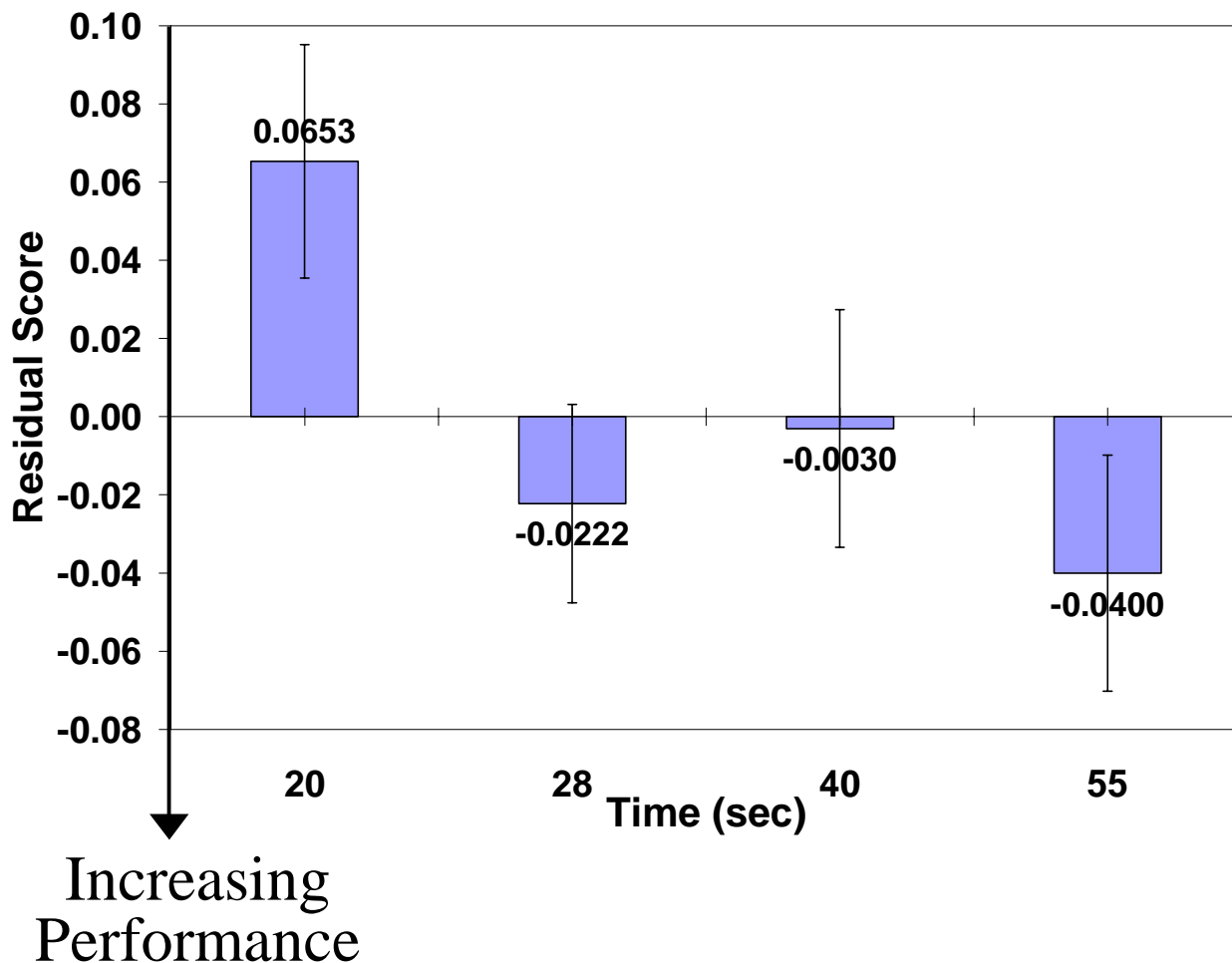
Interaction Effects

- Only <u>none</u> had sig. improvement with time
- <u>Hazard</u> better than <u>none</u> and <u>time/fuel</u> < 55 sec, sig. at 40 sec
- <u>None</u> outperforms <u>hazard</u> and <u>time/fuel</u> at 55 sec, while is the worst at 20 sec
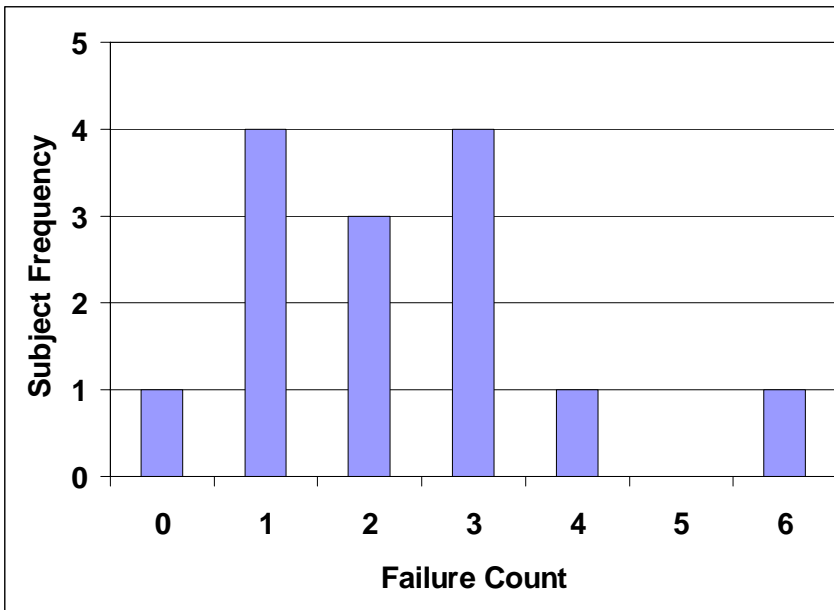- Performance decreases at times dependent on auto level

Temporal Benefit of Automation

- Idea of "Characteristic Time" (CT)
  - Period of *beneficial* time from having auto assistance

- Possible linear metric
  - Similar slopes
  - Intercept quantifies relative auto benefit

- $CT_{Full} > 55$ sec

- $CT_{Hazard} \cong 55$ sec

- $CT_{Time/Fuel} \leq 20$ sec

Increasing Auto Benefit

Auto Benefit (None - Auto)

$y = -0.0028x + 0.4486$

$y = -0.0032x + 0.1783$

$y = -0.0026x + 0.0589$

△ Full
□ Hazard
◇ ToT & Fuel

Time (sec)

Failure Analysis

- Only 1 subject was perfect
- 14.3% failure rate, 32 of 224

A failed scenario had ≥1 of the following:
1. Hit a brown hazard
2. Arrived target outside of time window
3. Not enough fuel to complete mission

- Most failures with <u>hazard</u>
  – Contrary to quantitative performance
- 40 sec had fewest failures
  – While no quantitative improvement in performance after 28 sec
- Failures at 55 sec ≅ 20 sec

Failure Count	Time				
Automation	20	28	40	55	Grand Total
None	2	1	1	2	6
ToT & Fuel	0	3	2	3	8
Hazard	6	2	0	5	13
Full	2	1	1	1	5
Grand Total	10	7	4	11	32

Conclusions

- Automation does assist in time-critical decision making

  - Auto benefit decreases as available time increases

  - Auto benefit increases dependent on type and amount of information integrated by automation

- Moderate amounts of time may actually hinder performance over less time

- Subject data supported quantitative analysis

Future Work

- Develop a generalized model for decision support automation
- Identify information support needs of human
- Follow-on experiment
  - More specific to flight environment
  - Data points > 55 seconds to reach characteristic time
  - Further test interactions between partial and no automation